ID: 2756130

Modeling and Simulation of Electrical Activation of Acceptor-Type Dopants in Silicon Carbide

V. Šimonka[1)], A. Hössinger[2)], J. Weinbub[1)] , and S. Selberherr[3)]
[1)] Christian Doppler Laboratory for High Performance TCAD, Institute for Microelectronics, TU Wien, Gußhausstraße 27-29/E360, 1040 Wien, Austria
[2)] Silvaco Europe Ltd., Compass Point, St Ives, Cambridge, PE27 5JL, United Kingdom
[3)] Institute for Microelectronics, TU Wien, Gußhausstraße 27-29/E360, 1040 Wien, Austria
E-mail: simonka@iue.tuwien.ac.at

Typical p-type doping species in silicon carbide (SiC) are aluminium (Al) and boron (B), which are commonly implanted into the semiconductor. In order to increase the electrical activation of the implanted species, it is extremely important to perform thermal annealing as a post-implantation step. We have therefore investigated the post-implantation annealing of Al- and B-doped SiC to predict the annealing temperature and the implanted concentration dependence on the electrical activation.

We have obtained several measurements [2-5] of the free carrier concentration as a function of sample temperature for various annealing temperatures T_A (Fig. 1). We have fitted these data with the charge neutrality equation [6] to obtain the acceptor concentrations N_A. For a corresponding T_A the electrical activation ratios R_{Act} have been calculated according to the total implanted concentration C_{Tot} (Fig. 2) via: $R_{Act} = N_A / C_{Tot}$. We have proposed an empirical relation to characterize R_{Act} as a function of T_A [7] (solid line in Fig. 2). The proposed relation has been implemented in Silvaco's Victory Process simulator [8], together with the model parameters for the Al and B dopants, to evaluate the gathered findings in the context of full process simulations. Additionally, another set of parameters was obtained by fitting the semi-empirical model from [8] to N_A (obtained in Fig. 1) as a function of C_{Tot}. Based on our implementation we are able to predict the activation of the implants in SiC for various T_A. The evaluation of both dopant species is consistent with the results presented in [1, 5, 9-11] and is essential to optimize the post-implantation annealing processes. Finally, we have performed two-dimensional simulations of the implantation and annealing process for a simple SiC diode (Fig. 3) using parameters and model extensions developed in this study and compared doping profiles with experimental findings.

In summary, this study has enhanced the process simulation capabilities for SiC annealing with the proposed empirical relation of the electrical activation ratio and the semi-empirical model parameters for the Al and B species in SiC. We have performed multiple simulations and obtained the model predictions of acceptor-type states in SiC after high temperature post-implantation annealing.

The financial support by the *Austrian Federal Ministry of Science, Research and Economy* and the *National Foundation for Research, Technology and Development* is gratefully acknowledged.

[1] T. Kimoto and J. A. Cooper, Fundamentals of Silicon Carbide Technology: Growth, Characterization, Devices and Applications (John Wiley & Sons, Singapore, 2014).
[2] A. Parisini, *et al.*, J. Appl. Phys. 118, 035101 (2015).
[3] Y. Negro, *et al.*, J. Appl. Phys. 96, 4916 (2004).
[4] T. Troffer, *et al.*, Physica Status Solidi 162, 277-298 (1997).
[5] T. Tsirimpis, M. Krieger, H. B. Weber, and G. Pensl, Mater. Sci. Forum 645, 697-700 (2010).
[6] C. M. Zetterling, Process Technology for Silicon Carbide (INSPEC, United Kingdom, 2002) p. 56.
[7] V. Šimonka, A. Hössinger, J. Weinbub, and S. Selberherr, SISPAD 2017, submitted.
[8] Victory Process: http://www.silvaco.com/products/tcad/process_simulation/victory_process/victory_process.html .
[9] N. S. SaksA, V. Suvorov, and D. C. Capell, Appl. Phys. Lett. 84, 5195 (2004).
[10] N. S. SaksA, K. Agarwal, S-H. Ryu, and J. W. Palmour, Appl. Phys. Lett. 90, 2796 (2001).
[11] M. A. Capano, *et al.*, J. El. Mat. 27, 370-376 (1998).

a) b)

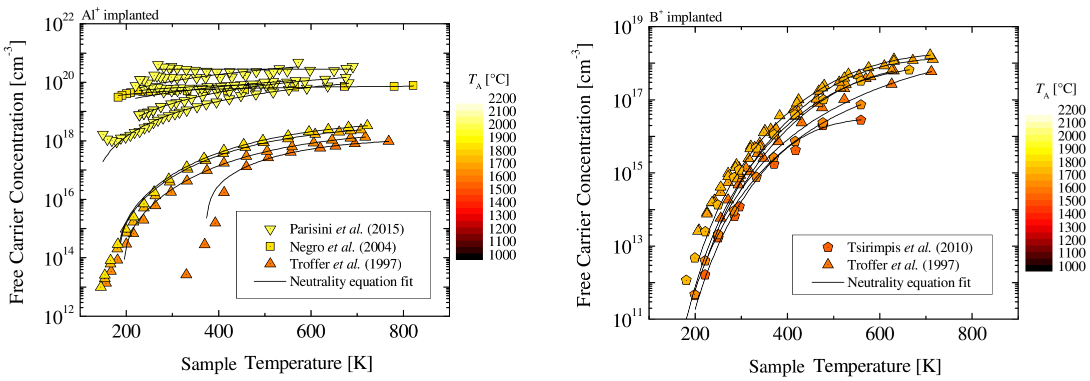

Fig. 1. Free carrier concentration as a function of sample temperature for **a)** Al and **b)** B implanted SiC. The symbols represent measurements, the solid lines refer to the neutrality equation fits, and the colors represent various annealing temperatures.

a) **b)**

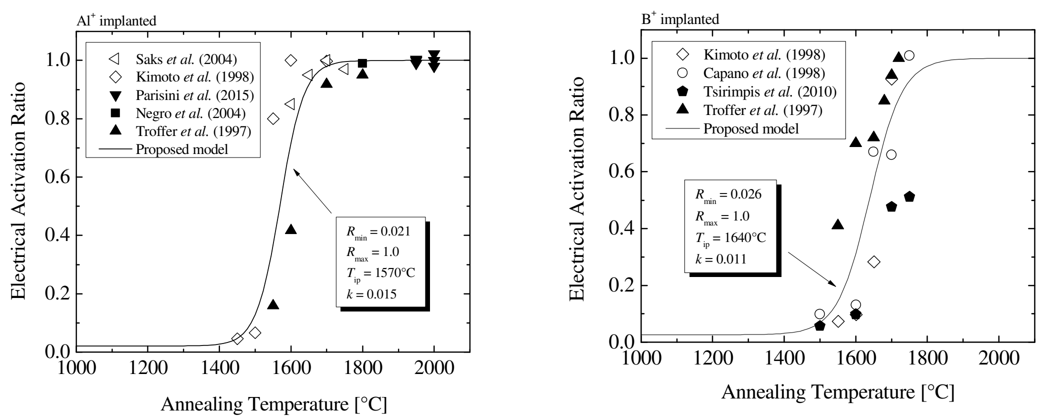

Fig. 2. Electrical activation ratio of **a)** Al and **b)** B acceptors as a function of annealing temperature. The open symbols refer to results presented in [1, 9, 11], the closed symbols are our results from Fig. 1, and the solid lines show the fit with the proposed relation of the electrical activation ratio [7].

a) **b)**

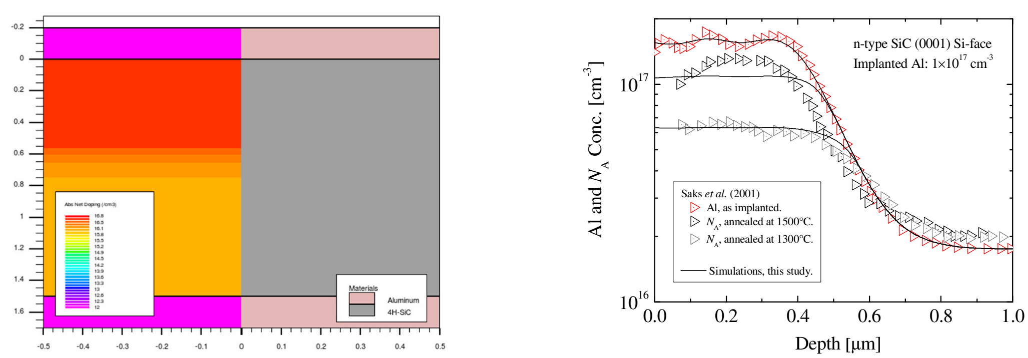

Fig. 3. **a)** Two-dimensional net doping profile from process simulations and **b)** cross-section of the depth profile with comparison to experimental data. Semi-empirical model, the proposed relation (Fig. 2), and the obtained model parameters were used for the simulations. Symbols refer to experimental findings from [10] and solid lines are simulations with identical variables as used in experiments.